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Biorefinery 101:
Maximizing Benefits and Minimizing Risks Associated with Implementing the Forest Biorefinery

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Intégration des procédés dans l'industrie papetière
Process Integration in the Pulp & Paper Industry

ÉCOLE POLYTECHNIQUE MONTRÉAL

6 April 2010

PSE Seminar, Department of Chemical Engineering, Carnegie Mellon University

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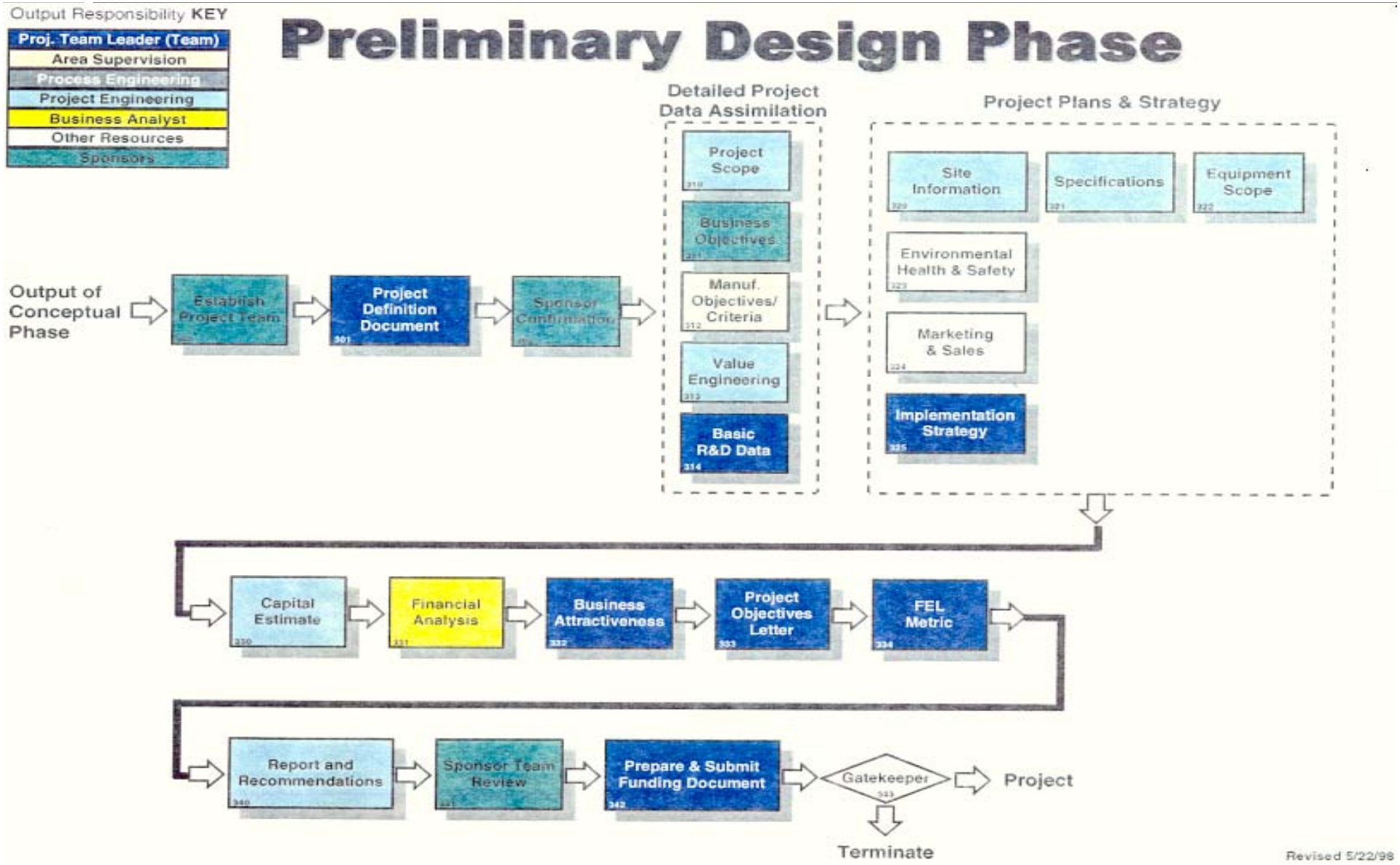
Process Integration in the Pulp & Paper Industry

Preliminary Design Process in a Large Forestry Company



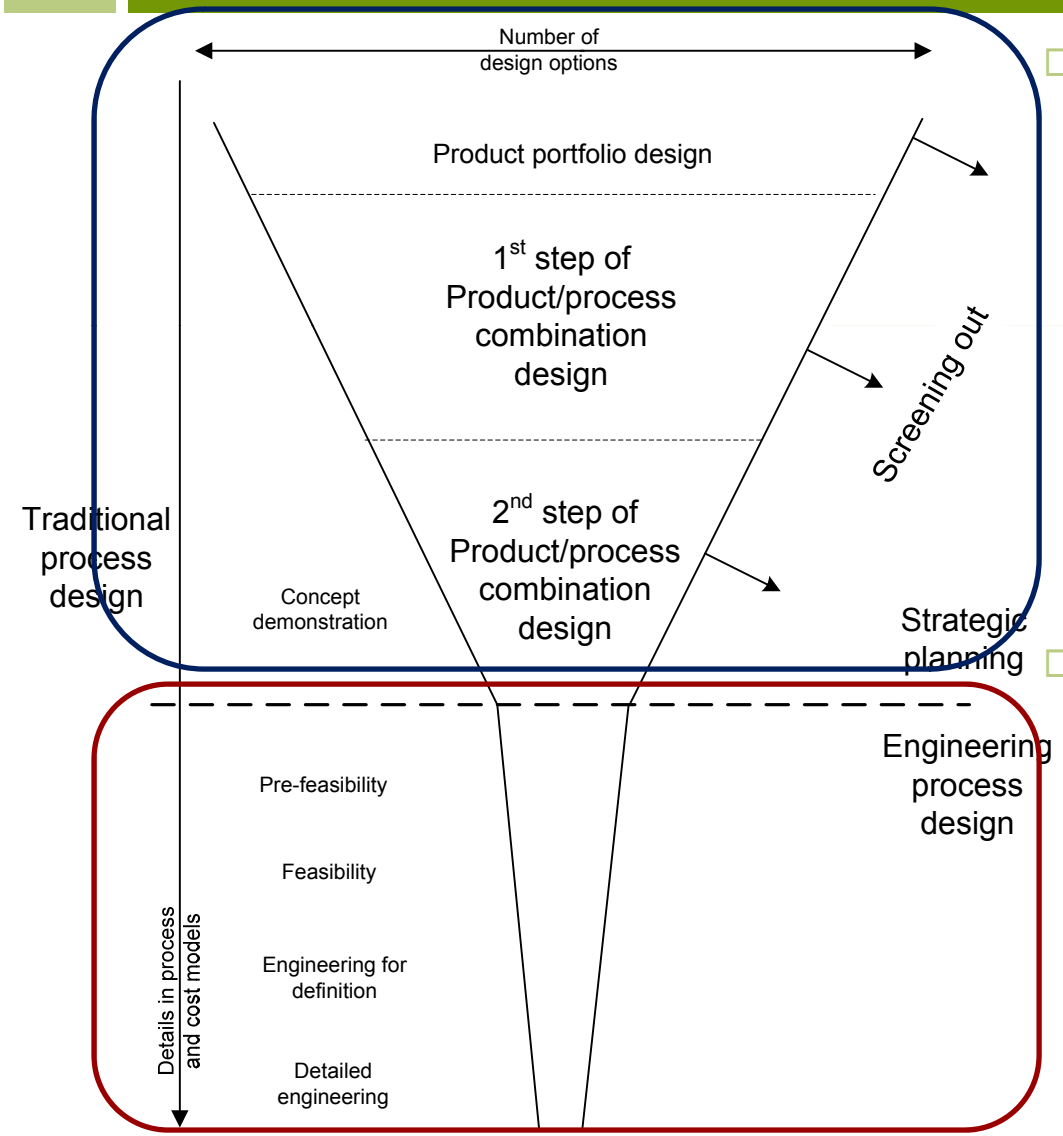
Process-Centric and Product-Centric Design Concepts

- "*Towards a Product-Centered Chemical Industry - Rethinking the Role of R&D and its Interaction with Marketing and Business Strategy*" FOCAPD (2004), and AIChE webcast (2004)

George Stephanopoulos, MIT

- Chemical Engineering is moving from being process-centric to product-centric
- Product centered: market trends → product specifications → components and subsystems → chemicals and materials → manufacturing systems design

Product and Process Design in Practice



- **Strategic Product-Process Design**
  - Generation of process-product alternatives
  - Very early stage design
  - Significant uncertainty
  - Long-term evaluation metrics for sustainable business evolution
- **Classical Process Design**
  - Pre-feasibility, feasibility, definition, detailed engineering
  - Focus is on maximizing ROI or IRR

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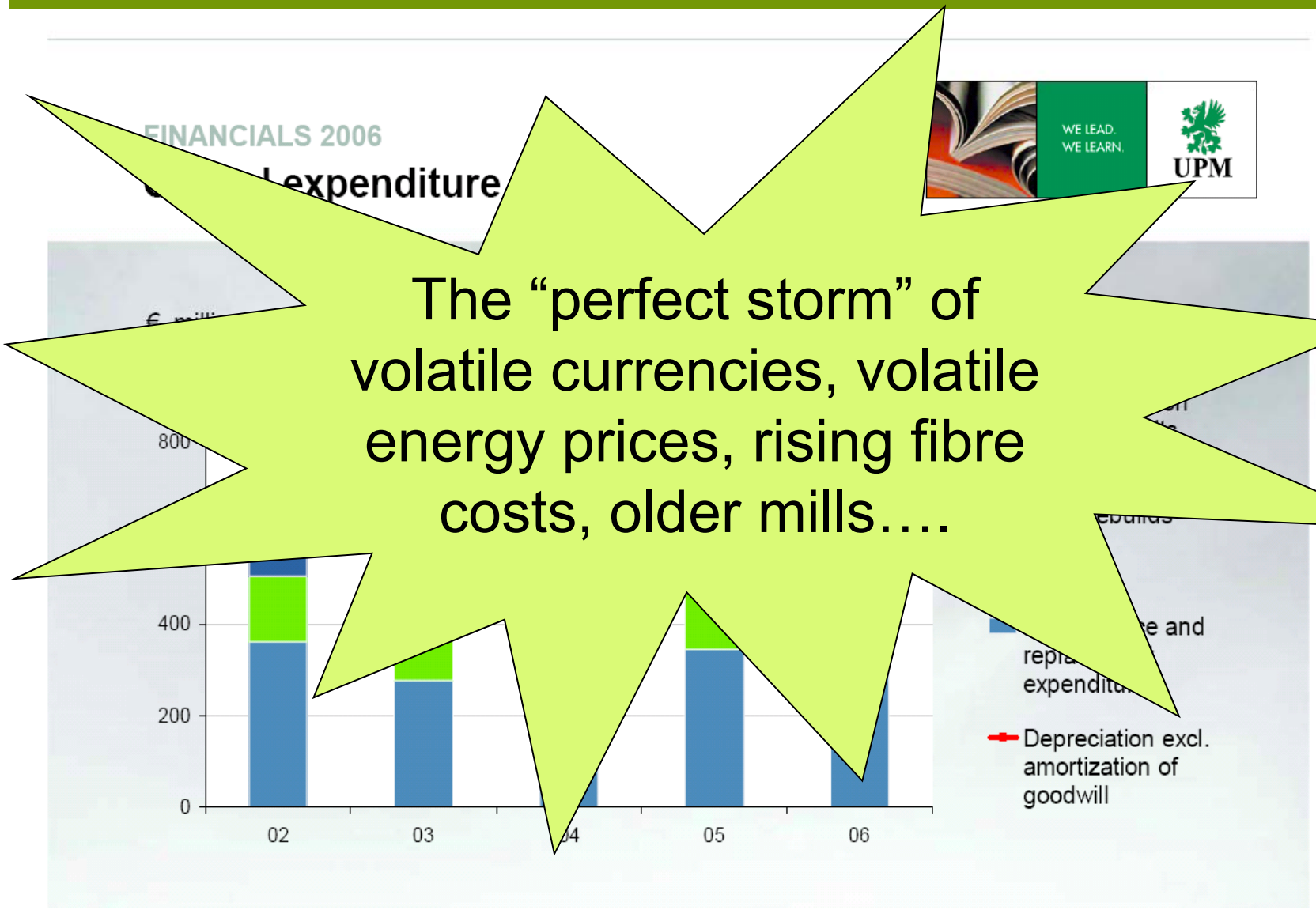
"Economic Stalement" for North American Forestry Companies



The "perfect storm" of volatile currencies, volatile energy prices, rising fibre costs, older mills….

Some Forestry Industry Survival Strategies

- Go for Survival in Commodities, or *Make the Most of Our Existing Industry*
- Buy/Build Elsewhere In Emerging Markets, or *Make the Most of Our Pulp and Paper Competency in Emerging Economies*
- Diversify Core Business with Marketing & Technological Partners, or *Make the Most of Our Existing Value Chain by Migration to New Business Paradigms*

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→ **The Forest Biorefinery!**

Forest Biorefinery Definition

- One forest biorefinery definition:

  The full utilization of incoming woody biomass for the production of:

  - Wood products
  - Pulp and paper products
  - Energy
  - **Biofuels and biochemicals**

- Another (more practical) forest biorefinery definition:

  = Maximizing the economic value from trees

  = Improved business model

  = Corporate transformation…

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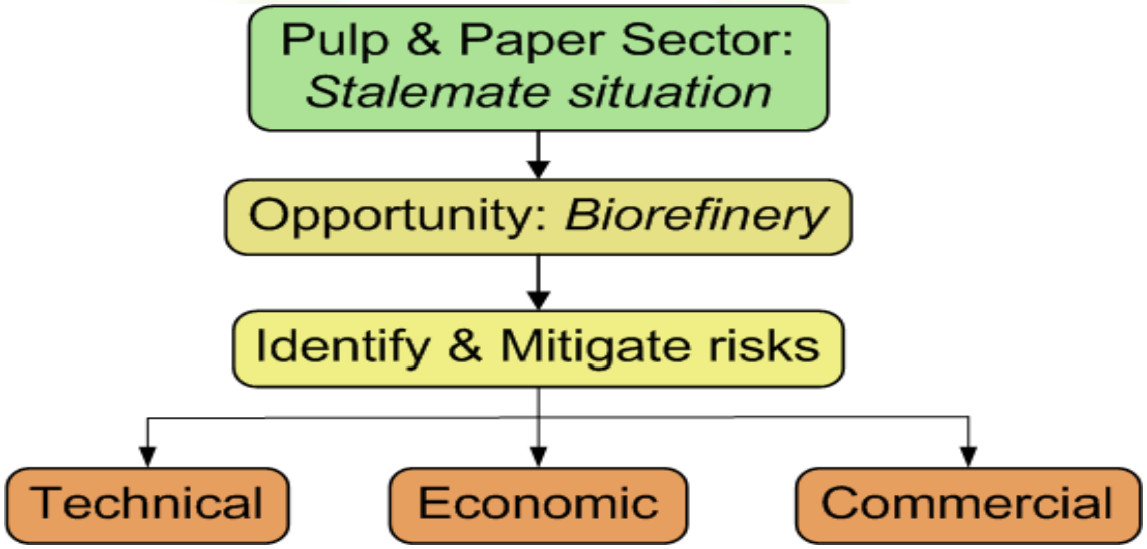
Biorefinery Implementation Barriers

- The leadership of most forestry companies understands what the biorefinery is, and likes the idea of revenue diversification…
- However management doesn't know how to go about defining the company strategy, and is concerned about risks to the core business…



Objective of this Presentation

To present (certain) design issues that should be considered by forestry companies seeking to identify promising biorefinery pathways

...based on biorefinery design activities, consulting activities, and pulp and paper company strategic planning

...leading to an **corporate strategy** and multidisciplinary **design methodology,** employing **product design** and **process systems engineering**.

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Presentation Outline

- Leading forestry companies are implementing the biorefinery
- Key biorefinery concepts and definitions
- Biorefinery **implementation strategy** for forestry companies
- Overall **design methodology** for the forest biorefinery
- Some interesting **process systems engineering** projects that we are applying in our Engineering Design Chair

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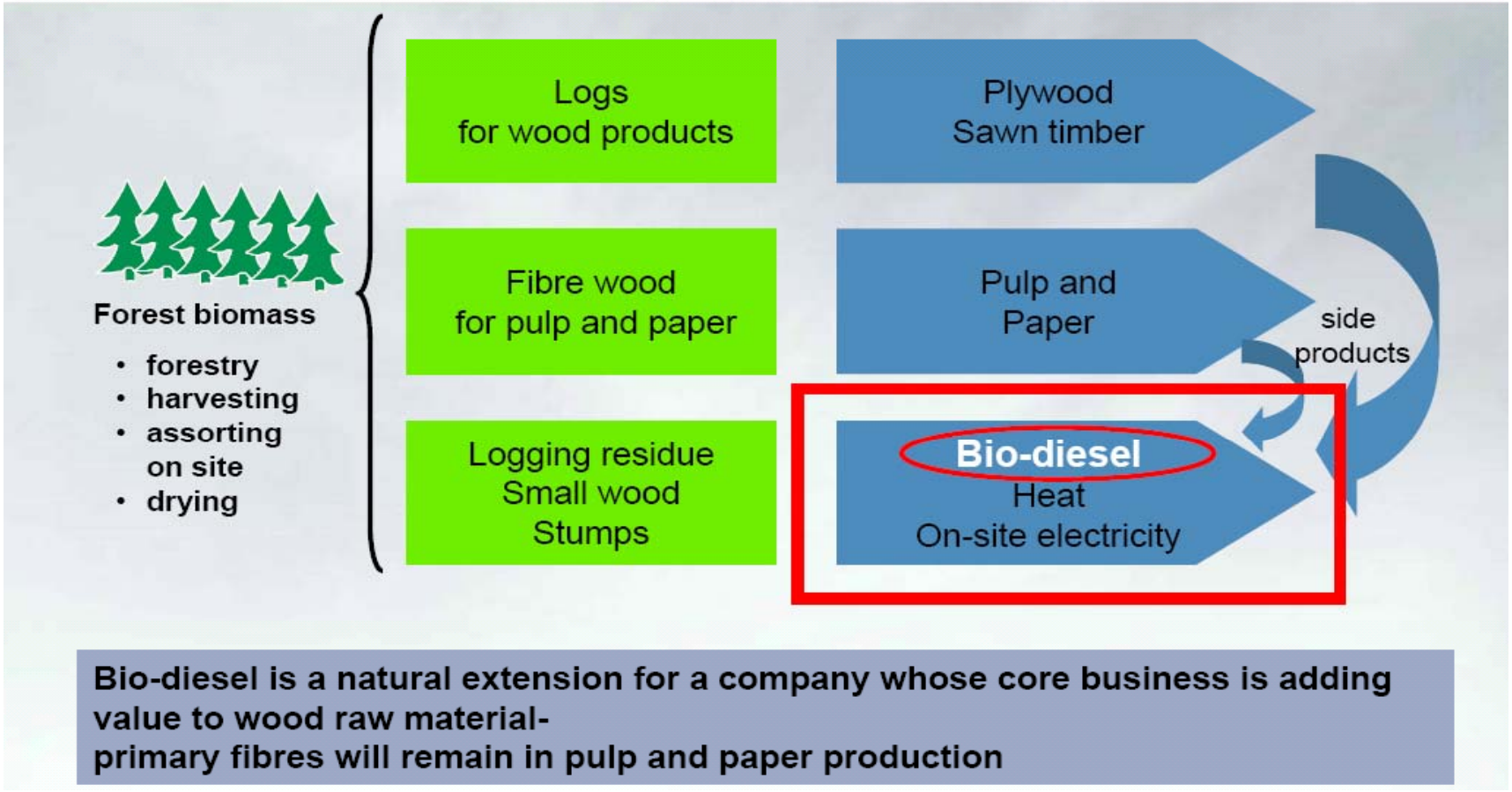
UPM-Kymmene Report to Investors

PORTFOLIO DEVELOPMENT – BIODIESEL

Sustainable optimisation of gain from biomass base adds value



Bio-diesel is a natural extension for a company whose core business is adding value to wood raw material-
primary fibres will remain in pulp and paper production

Catchlight Energy

"Billions of Gallons of Transportation Fuels Annually"

Biofuels from the Forest

- 50-50 joint venture company
- Develop and commercialize technology for converting cellulose-based biomass
- For use in renewable transportation fuels from non-food sources

Chevron

Catchlight Energy™
A Chevron | Weyerhaeuser Joint Venture

Weyerhaeuser

UBS Global Paper & Forest Products Conference Presentation, 2008

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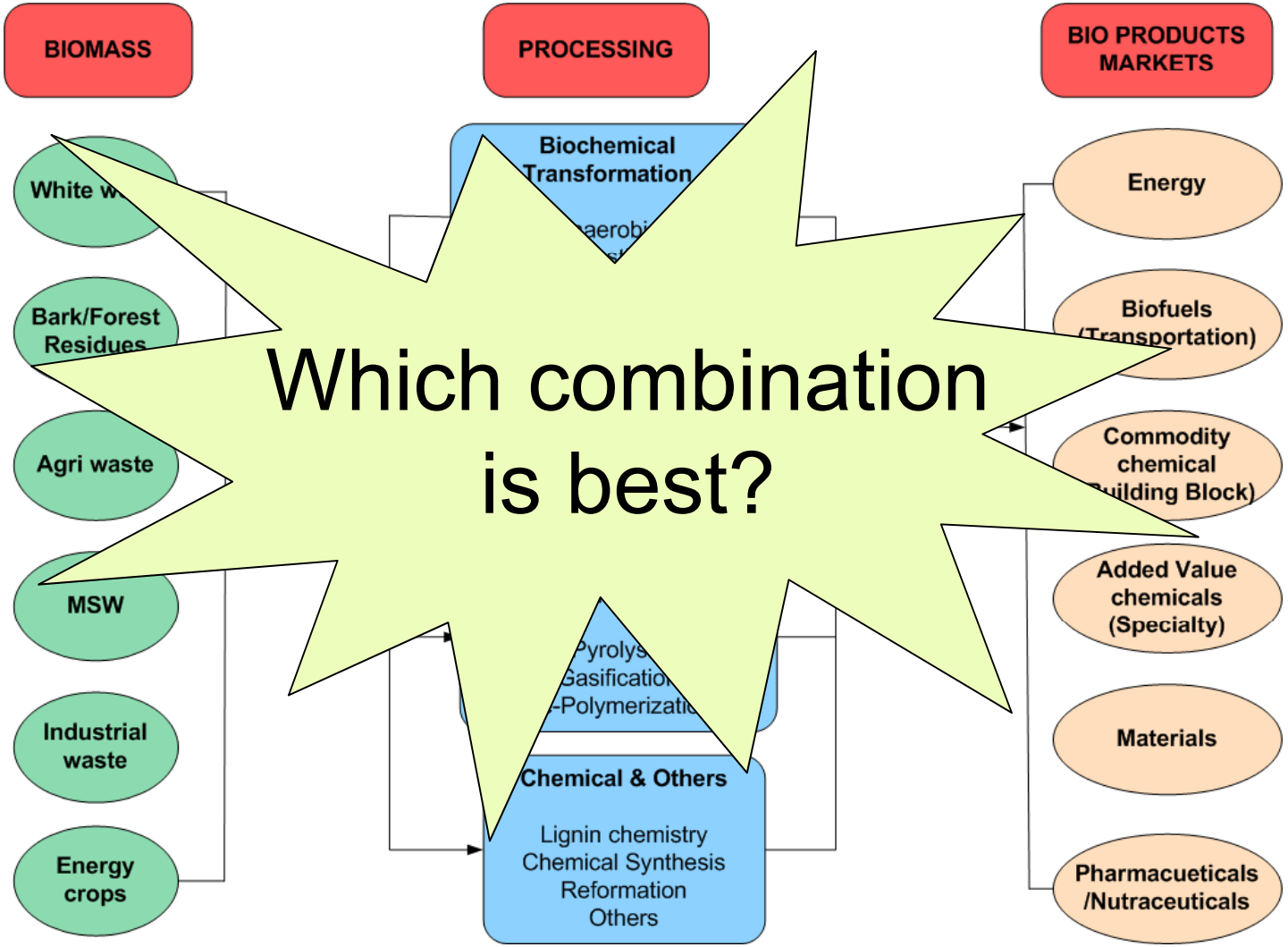
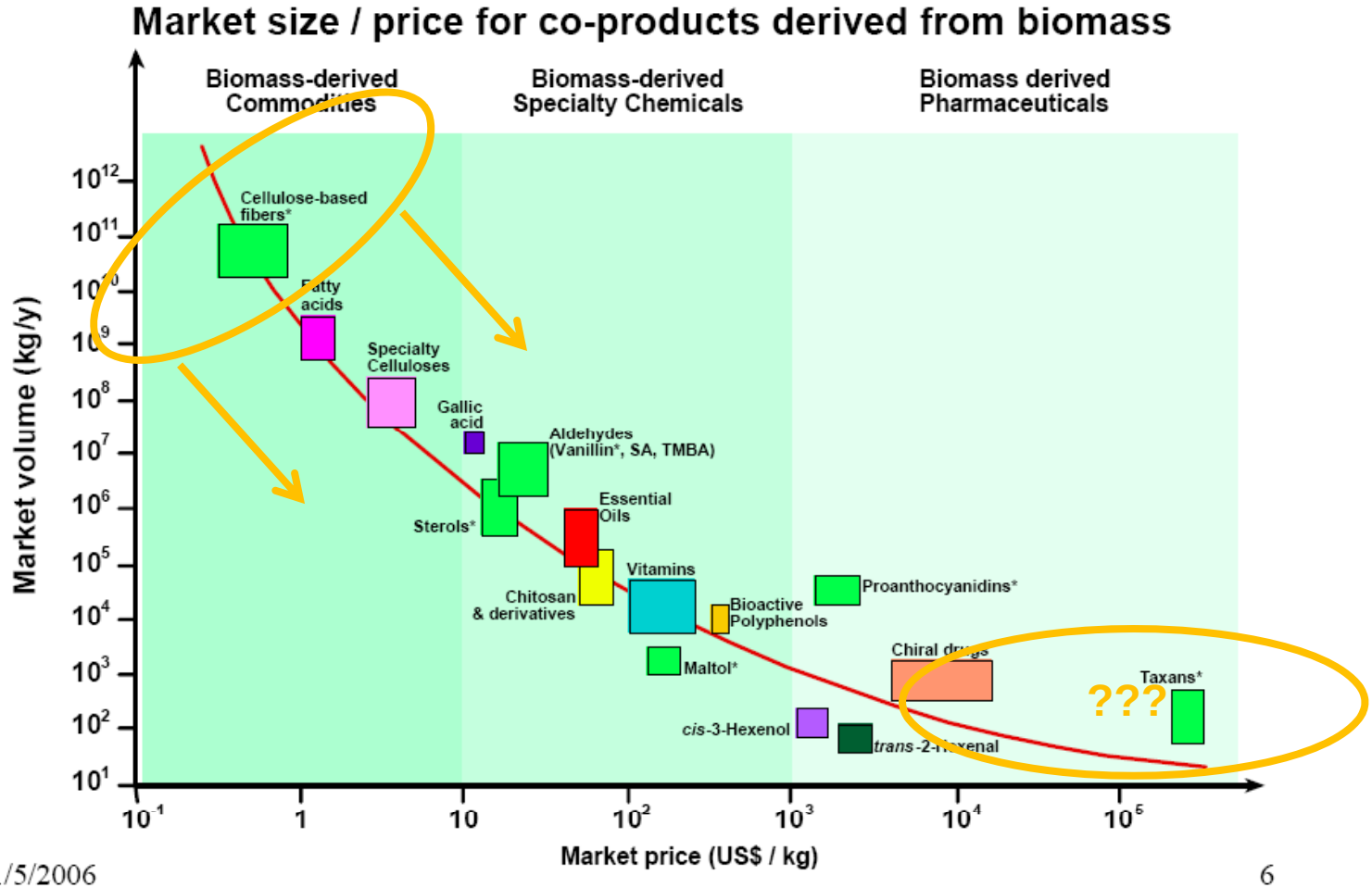
Identifying the Right Biorefinery Configuration is Complex…

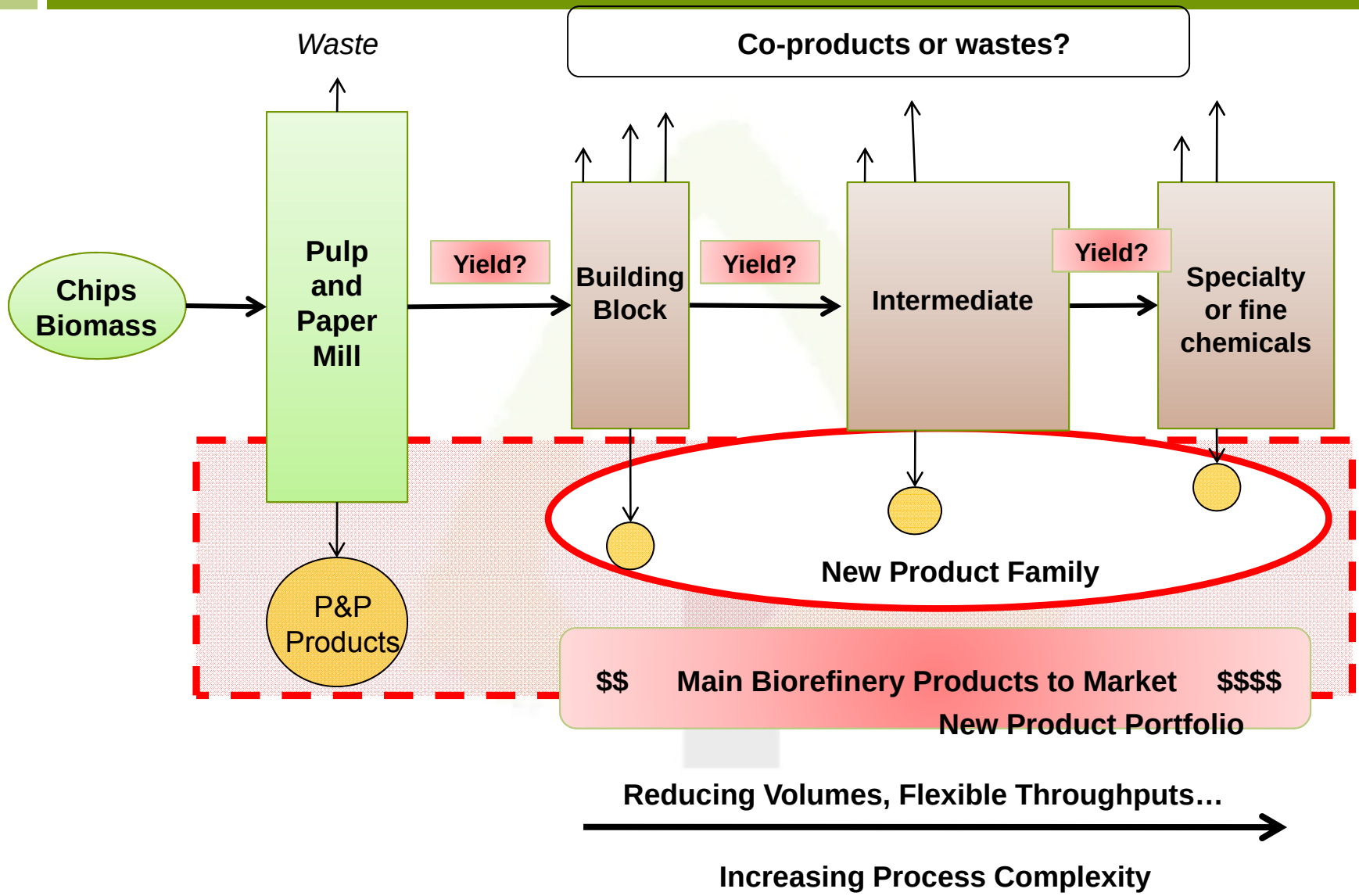


Volume-Margin Trade-Offs for the Forest Biorefinery

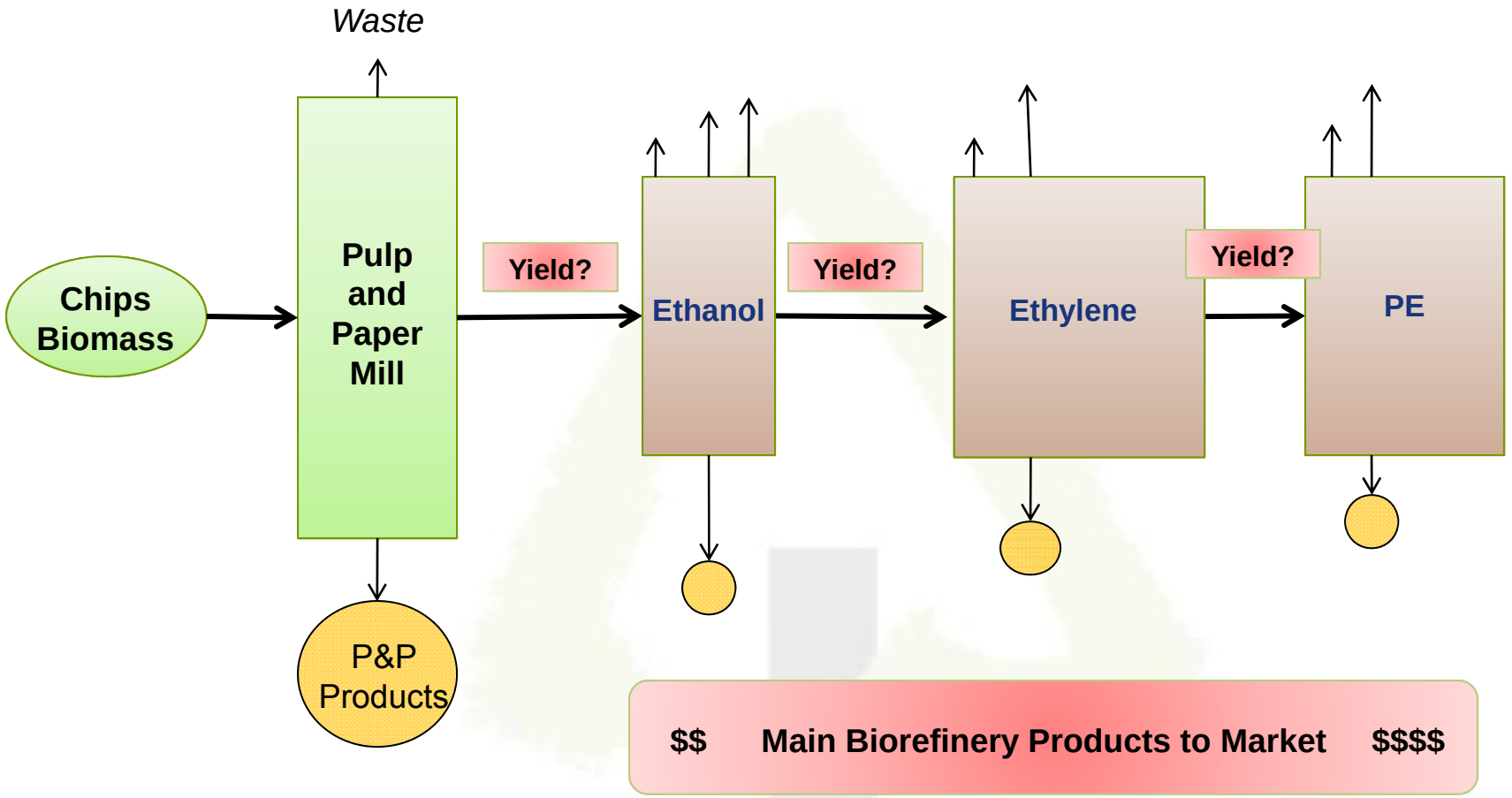


Industry Canada Nov 2005

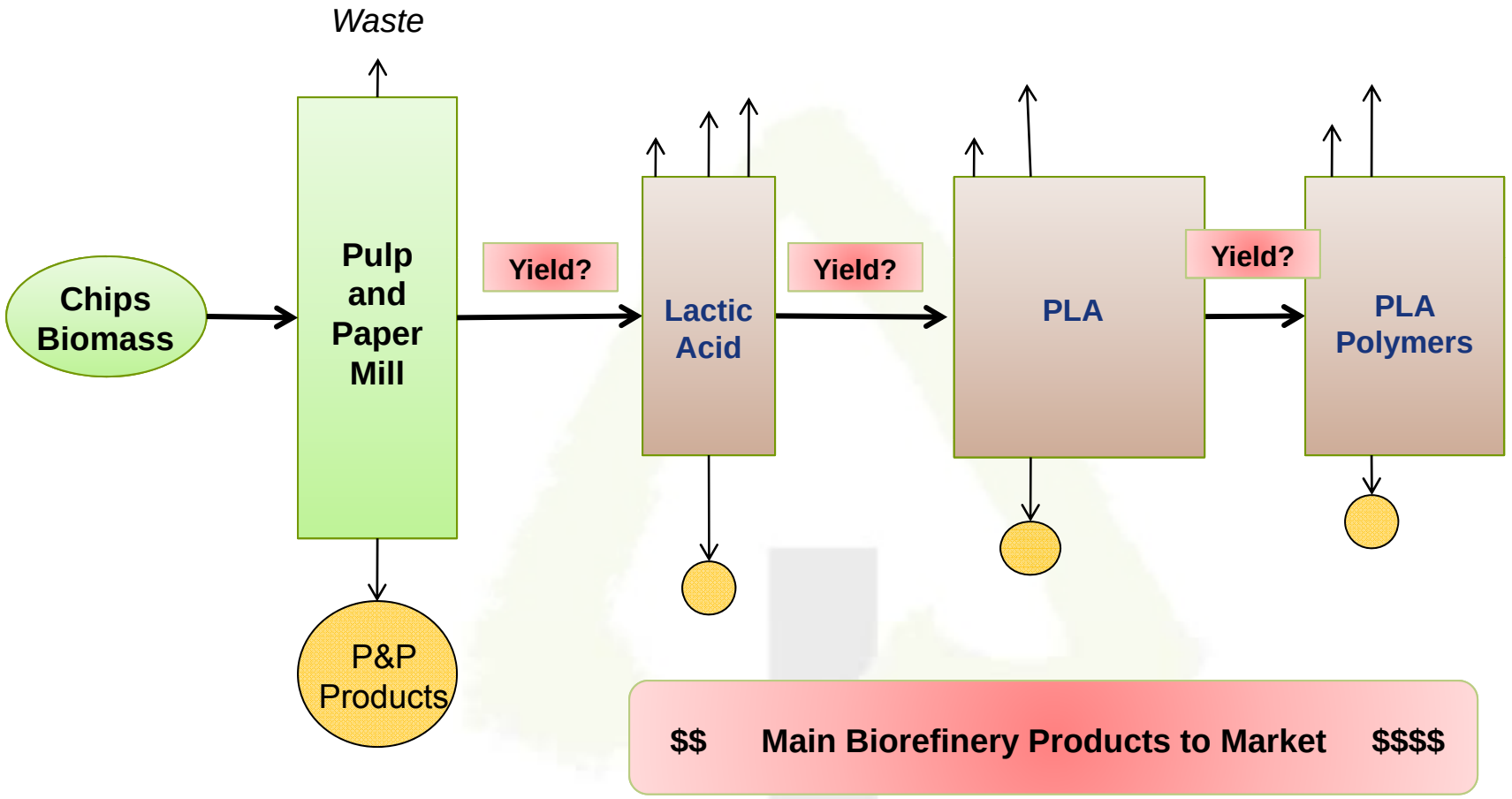
Definition: Building Blocks and Derivatives…



Example: Product Replacement in Mature Supply Chains…



Example: Product Substitution in Emerging Supply Chains…



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Key Competitive Factors

- Maximize forestry company competitive advantages:
  - Access to biomass availability and harvesting know-how
  - Existing infrastructure in close proximity to forest biomass
  - Established SC for wood, pulp and paper products

- Address forestry company competitive disadvantages:
  - Lack of capital
  - Lack of product development culture
  - Lack of knowledge of product quality requirement, SC practices etc for new bioproducts

Some Lessons Learned from Our Case Studies Thus Far…

- Biorefinery **technology** will be critical for competitive position in the short-term, the **unique supply chain** will be critical for competitive position in the longer-term
- In order to be competitive in the longer term: **product design**, before process design
- Meet profitability targets for varying market conditions by designing for **manufacturing flexibility**
- The key to success in the forest biorefinery will be through implementing "**knowledge-based manufacturing**" in conjunction with flexible manufacturing and advanced supply chain management

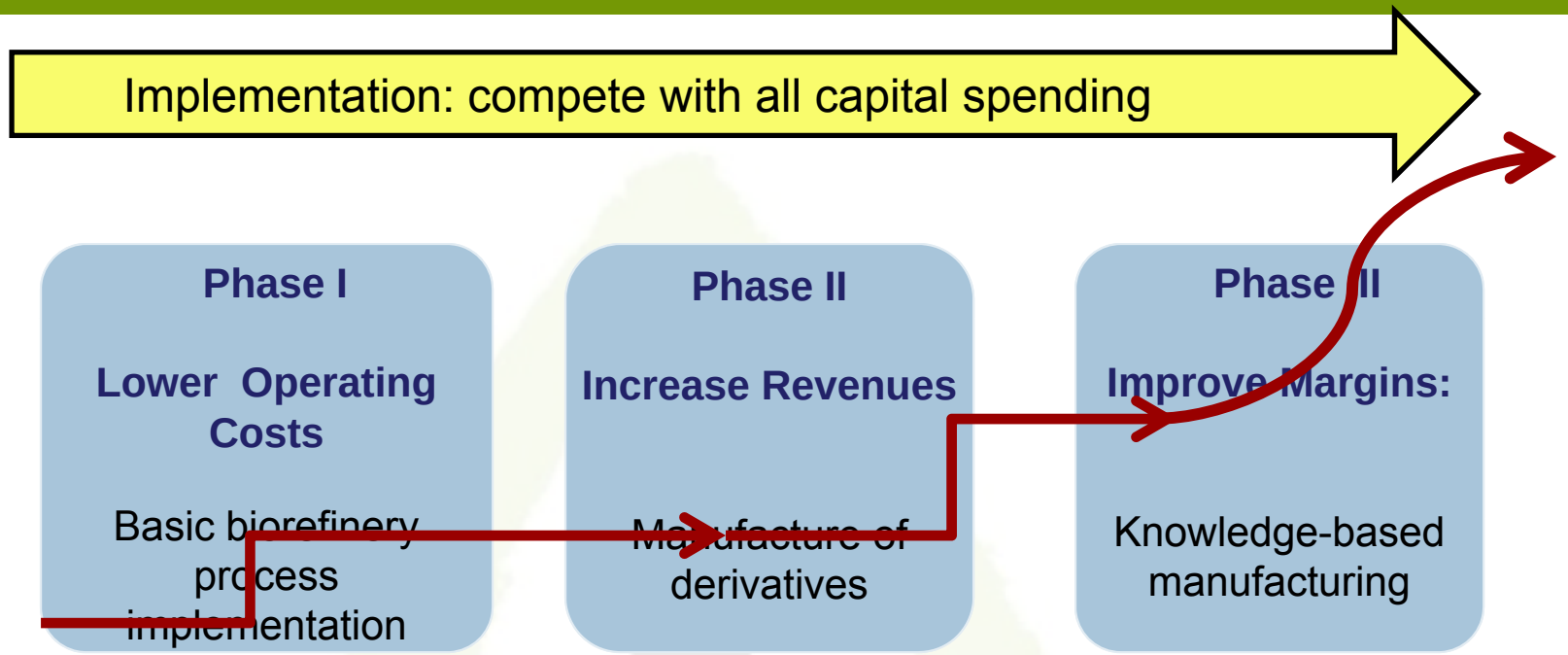
Strategic Approach for Implementing the Biorefinery

Implementation: compete with all capital spending

Phase I	Phase II	Phase III
Lower Operating Costs	**Increase Revenues**	**Improve Margins:**
Basic biorefinery process implementation	Manufacture of derivatives	Knowledge-based manufacturing
Main challenges		
Compete internally for capital	Select the most sustainable product platform and partner(s)	Company culture transformation SCM key to success

Strategic Vision: Phase III must determine Phase I

Strategic Approach for Implementing the Biorefinery



Biorefinery Goal: New Business Model

Margins improvement is a prerequisite

Strategic Vision: Phase III must determine Phase I

Strategic Approach for Implementing the Biorefinery

Shorter term **Implementation** *Longer term*

Strategic Design and Planning

Objectives for existing core business

Revenue diversification objectives

Competitiveness analysis/strategy for product options

Potential partnership targeting

Strategies for technology and business risk mitigation

Preliminary business model definition

Value Creation

Technology Disruption
Facility-level implementation

Lower Operating Costs

Replace fossil fuels at mill and/or
Produce "building block" biorefinery chemicals
Lower risk technologies

Increase Revenues

Manufacture of derivatives
Market development for new products
Higher process complexity and technology risk
Partnership in place

Business Disruption
Enterprise-level implementation

Core Business
Margins improvement

Coordination of decision making
ABC accounting
SC policy change
Partnership agreement

Transformed Business
Margins Improvement

Advanced ERP & decision tools implementation (knowledge-based mfg)
Production flexibility
Partnership implementation

Value Capture

Strategy re-evaluation

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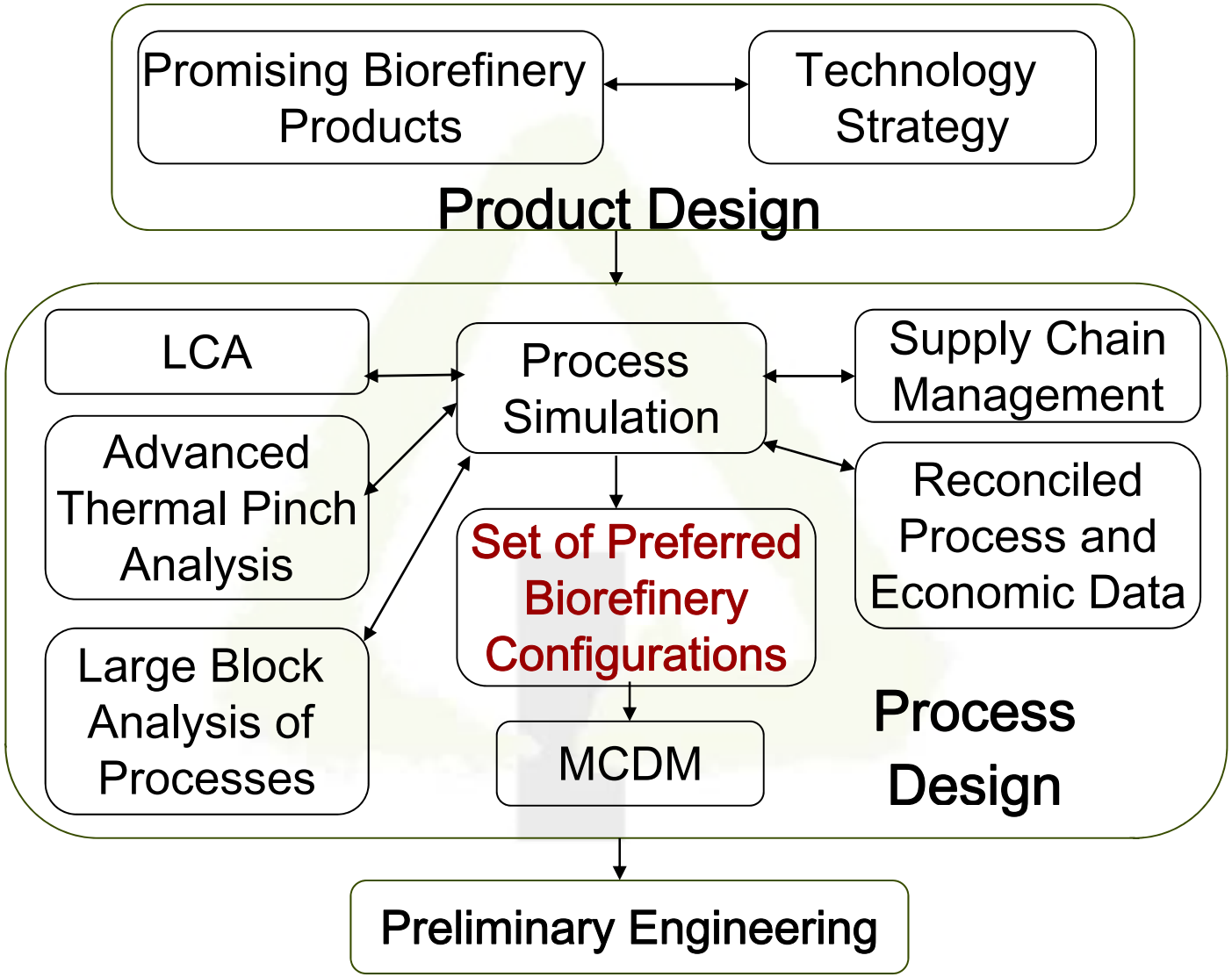
Overall Biorefinery Design Framework



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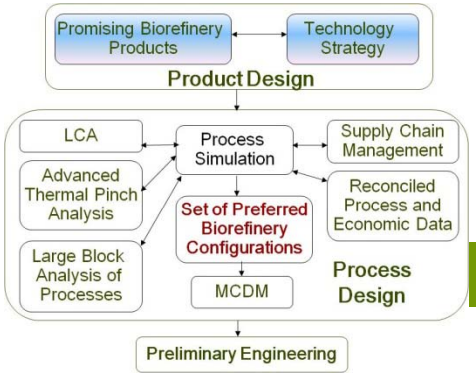
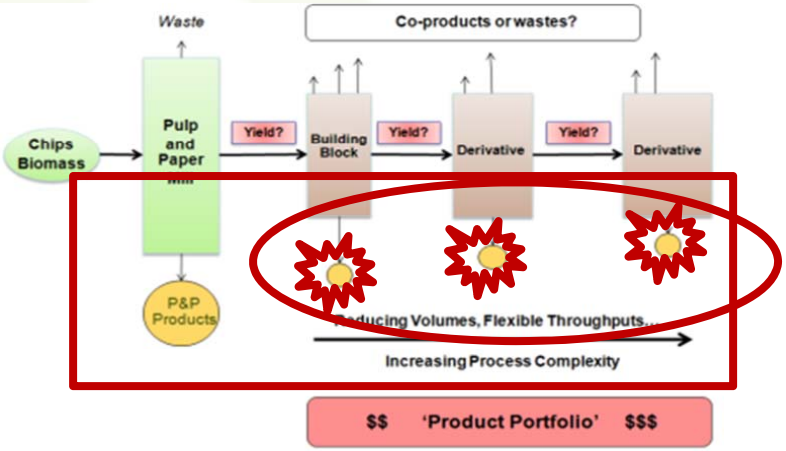
Product Design Through to Partner Identification...



Individual Product Analysis
Which replacement/substitution products should be considered?
Promising technologies, Product growth
Potential for competitive advantage with green product
Competitive manufacturing costs/existing value chain

Product family analysis:
Creating added value along the value chain
What are the competitive factors associated with the aggregated product family?

Risks?

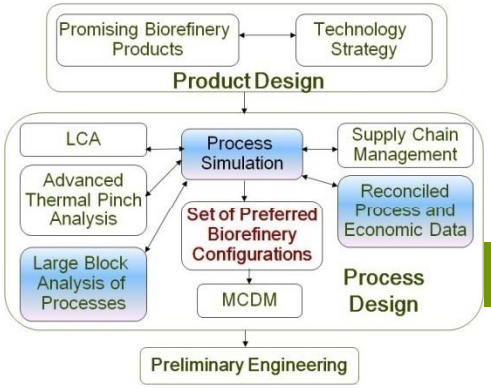


Risks?

Product Portfolio:
What potential new supply chain opportunities are there?
Will a unique SC result, that can't be achieved by others?

Risks?

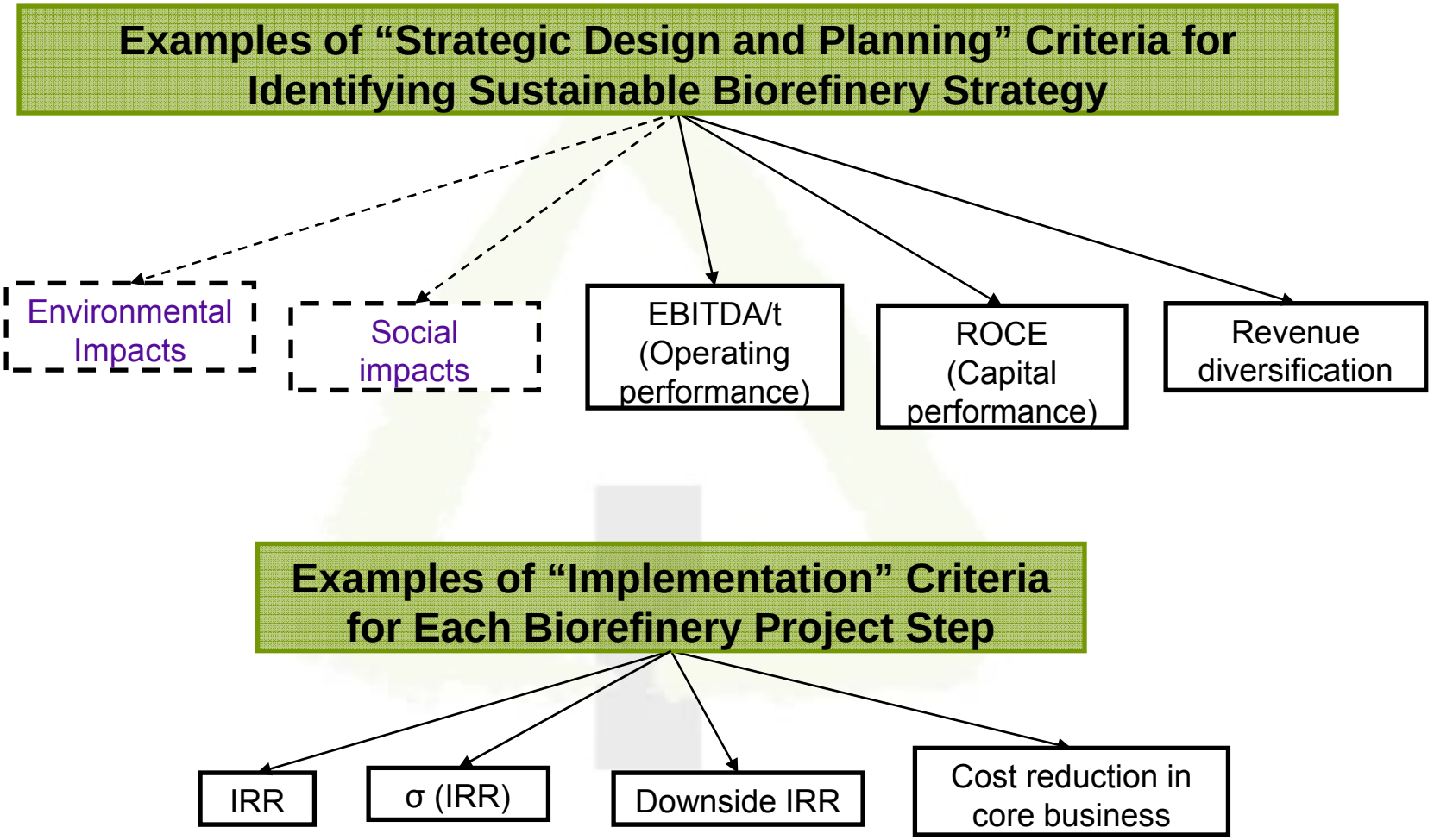
Partnership Selection:
Who are the promising partners for the candidate product families?
Do their corporate visions align with yours, i.e. implementing the biorefinery in partnership?

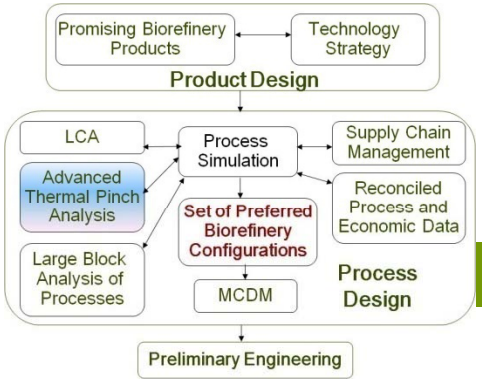


Techno-Economic Analysis: Some Key Questions

- What are the available feedstocks, and emerging processes available to manufacture the set of targeted products? Other "**show-stoppers**"?
- Is there a competitive opportunity through partnership with **innovative technology development** companies?
- How can the capital cost of the biorefinery be reduced through existing **mill infrastructure**?
- How will biorefinery implementation enhance the **core business competitive position**, by lowering the unit costs of pulp and paper products?

Techno-Economic Analysis: Key Evaluation Criteria

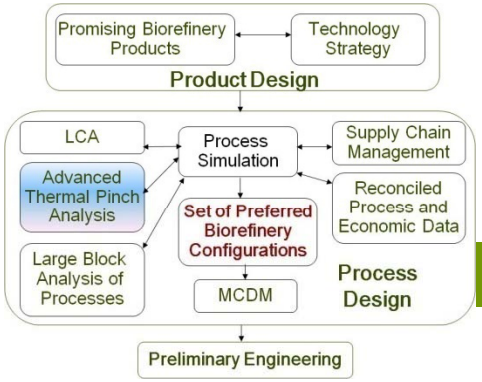




Energy Planning: Some Key Questions

- What is the practical **thermal pinch analysis** methodology for exploring the biorefinery?
  - Retrofit context
  - Simultaneous water use and energy use reduction

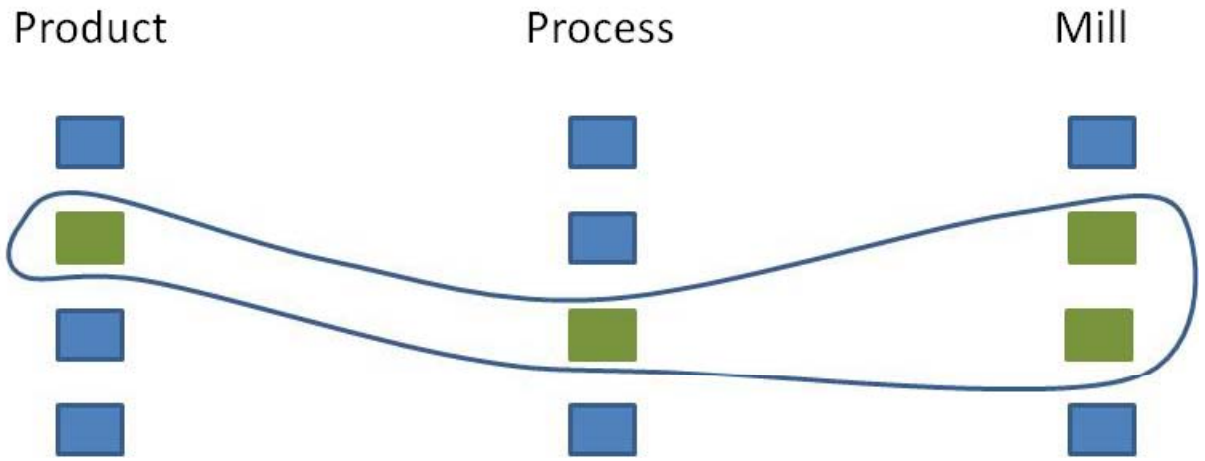
- Do we need to be as **energy efficient** as possible, in order to have the best energy profile for the biorefinery?

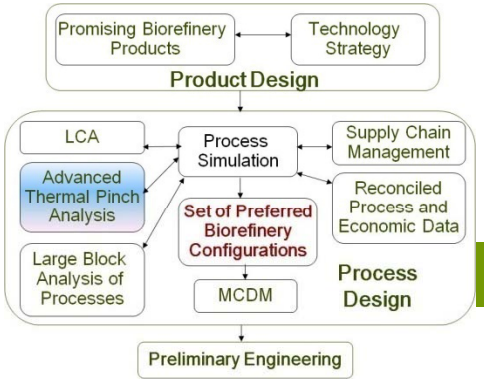


Energy Planning for the Biorefinery

Market → product → process →

Mass and energy balances for targeted biorefinery processes at targeted facilities…





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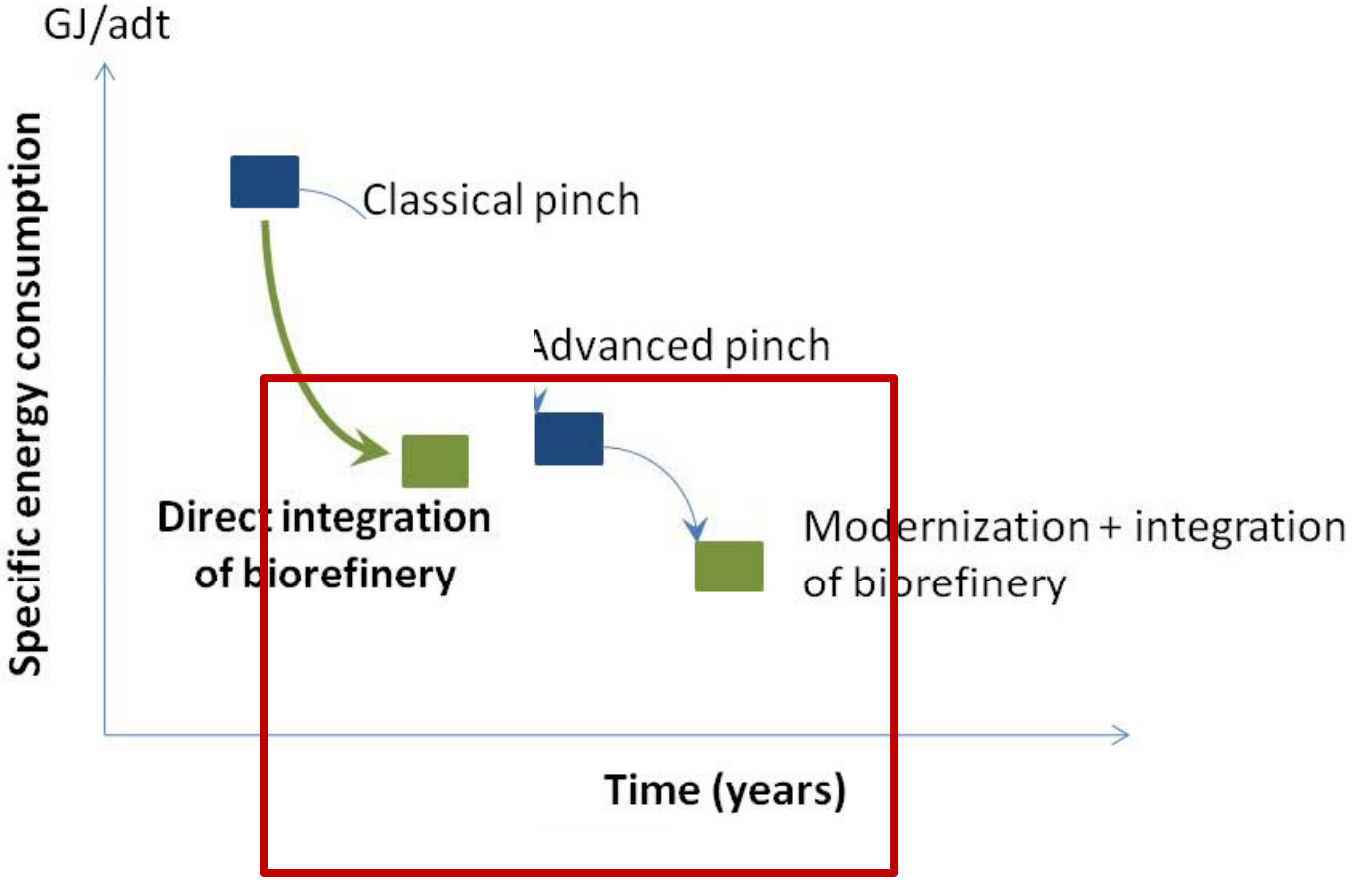

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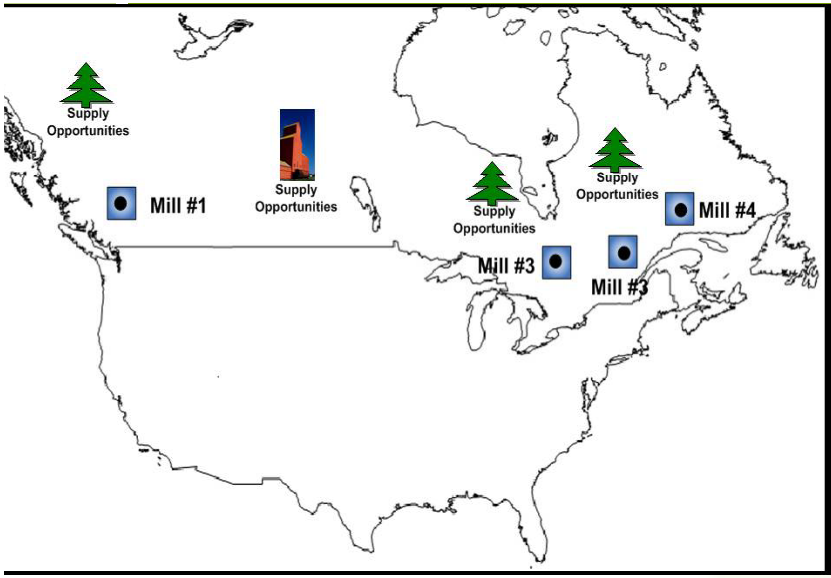
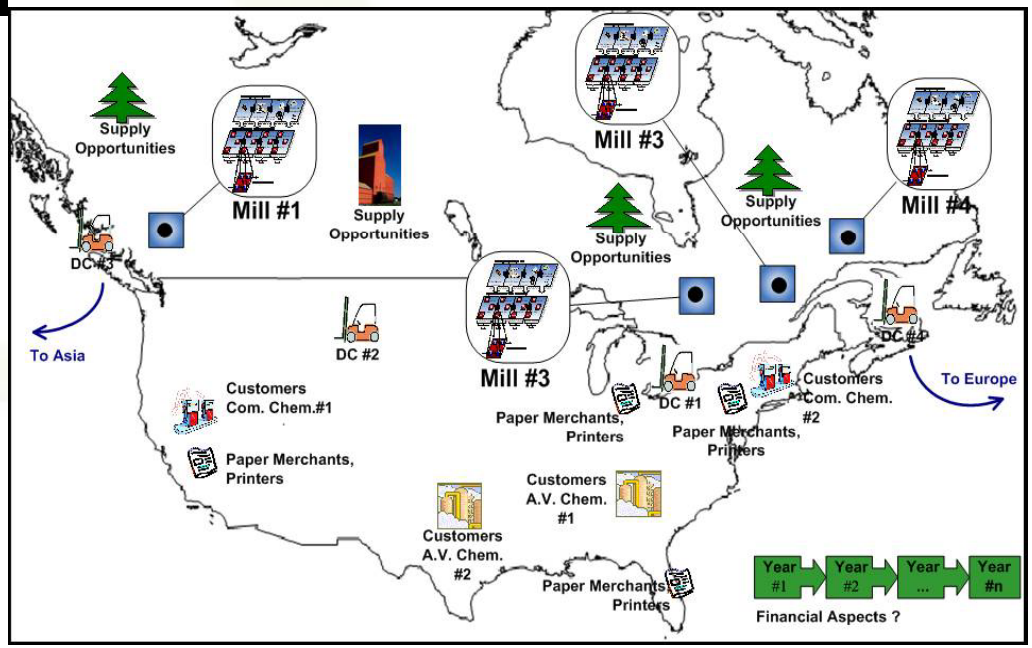
The Biorefinery Supply Chain will be Significantly More Complex



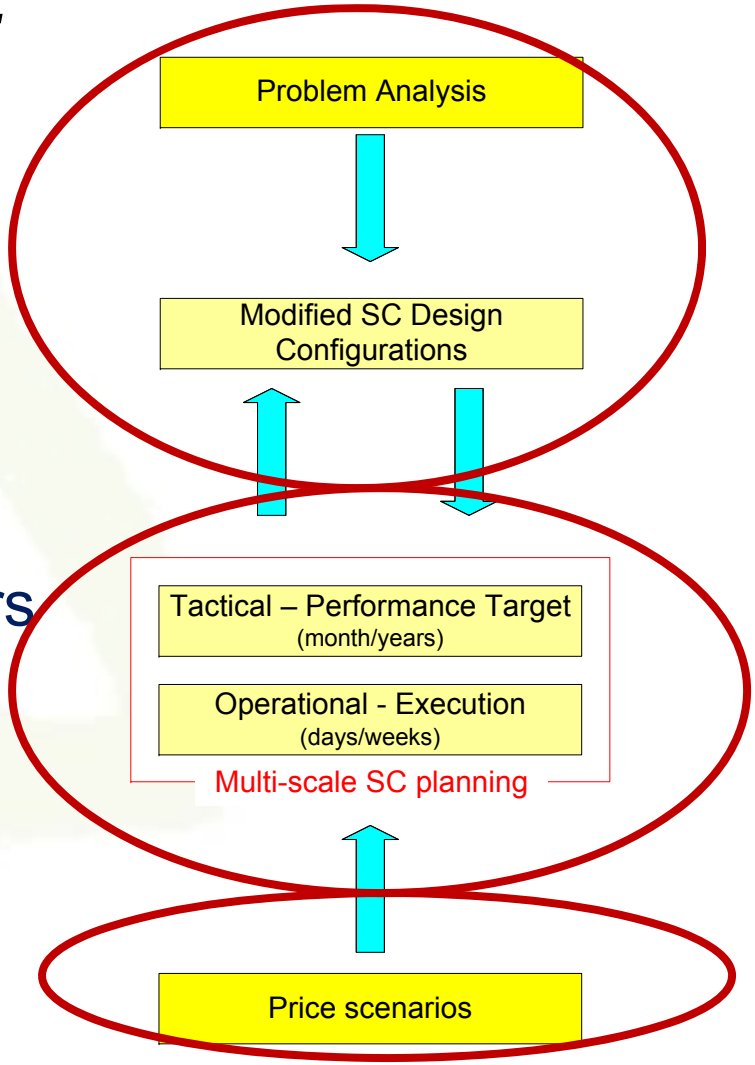
Existing SC

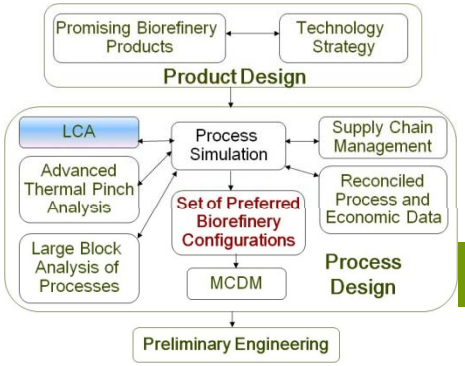
Biorefinery SC



Exploring the Biorefinery SC Design and Management

- ***For a given product portfolio:***
  - Fixed number of SC design configurations at the strategic level
  - Explore the margins-based SC management strategy: this implies a significant transformation…
  - Explore the impact of key factors on profit – especially price scenarios based on possible market conditions
  - Designing for manufacturing flexibility…





Biorefinery Environmental Impact: Life Cycle Thinking

- Boundaries
- **Allocation**
- Indicators
- **Normalization**
- **Weighting**

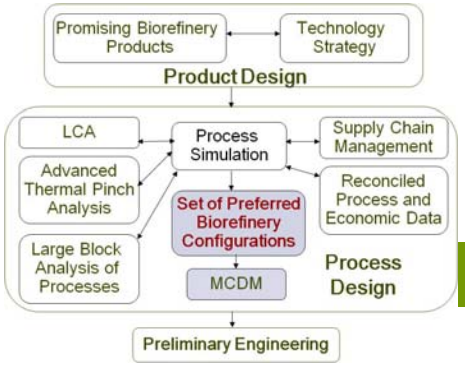
LIFE CYCLE ASSESSMENT

- Goal and scope definition
- Life cycle inventory
- Life cycle impact assessment
- Interpretation

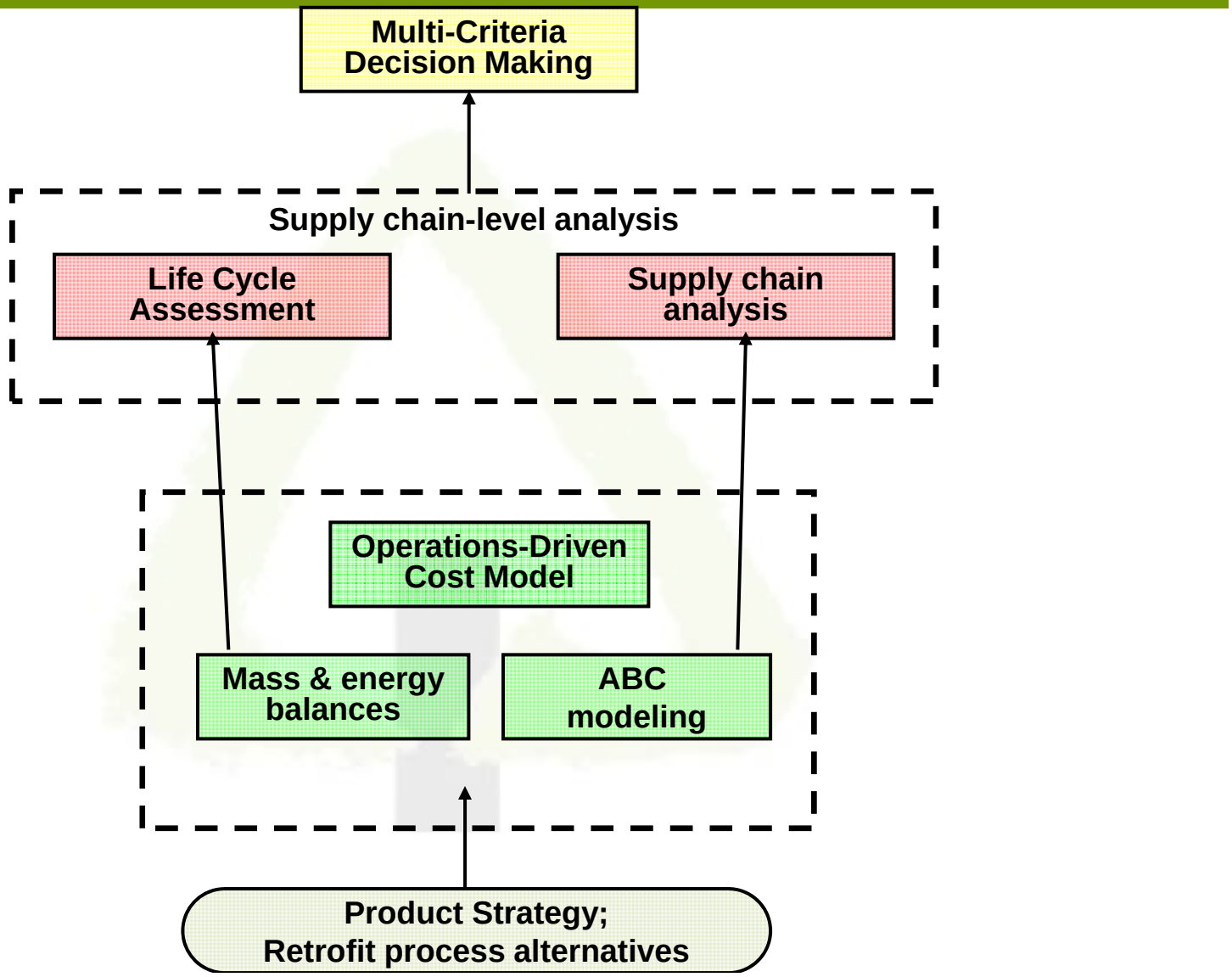
IMPLICATIONS OF METHODOLOGICAL CHOICES FOR PROCESS DECISION-MAKING

- ✓ Operational level: Continuous environmental improvement and environmental management systems
- ✓ Tactical level: Retrofit process design
- ✓ *Strategic level:* Forest biorefinery (FBR)

OTHER TOOLS



MCDM for Evaluating Biorefinery Sustainability…



Take-Home Messages...

- The **biorefinery** implies a company transformation, and requires that different decision metrics be calculated using a sustainability context

- **Risk mitigation** associated with the implementation of the biorefinery can be achieved with strategic planning:
  - Starting with market-based product portfolio design
  - Partner selection and partnership model are critical
  - SC design and management must be examined, incorporating issues of manufacturing flexibility…

- Advanced **product and process design methodologies** can be applied to determine the decision metrics of biorefinery options, and then these can be evaluated using MCDM

Thank you!

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